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Employing Blended Interaction to Blend the Qualities of Digital and Physical Books

Anwendung von Blended Interaction zur Vermischung der Eigenschaften digitaler und physischer Bücher

Blended Interaction_Ubiquitous Computing_Well-established Digital Concepts_Augmented Tabletop

Summary. This paper presents Integrative Workplace, a system which blends the qualities of digital and physical sources by augmenting physical books with properties of digital books and vice versa. On the base of Blended Interaction, we designed a system which helps users to interact with the new and unfamiliar functionality of digitally augmented books. In a user study, law students employed Integrative Workplace to work on a legal case. The positive feedback of participants indicated that we managed to design a system which is usable in a professional context. Furthermore, the study revealed evidence that digitally well-established concepts are a part of users' reality and need to be considered in the design of new user interfaces. The results of this user study encourage us to continue to use Blended Interaction in the design process of novel user interfaces with an unfamiliar functionality.

Zusammenfassung. In diesem Beitrag wird Integrative Workplace vorgestellt, ein Arbeitsplatz der physische Bücher mit den Eigenschaften digitaler Bücher anreichert und umgekehrt. Auf Basis des Design Frameworks Blended Interaction wurde ein System entwickelt, das Benutzern hilft mit der neuartigen Funktionalität von digital angereicherten Büchern interagieren zu können. In einer Nutzerstudie verwendeten Jurastudenten Integrative Workplace um einen Sachverhalt zu bearbeiten. Die positive Resonanz der Teilnehmer zeigt, dass das System rechtswissenschaftliches Arbeiten unterstützt. Darüber hinaus gab die Studie Hinweis darauf, dass etablierte digitale Konzepte ein Teil der Realität geworden sind und daher beim Design von Benutzerschnittstellen berücksichtigt werden müssen. Die Ergebnisse der Studie ermutigen uns, Blended Interaction auch weiterhin im Designprozess neuartiger Benutzerschnittstellen zu verwenden.

1. Introduction

In the Living Lab of the Blended Library (Heilig, Rädle, & Reiterer, 2011) we develop and investigate new user interface and interaction concepts to support research processes in the physical library of the future. It was designed and set up according to the needs of library users, which were extracted from an online questionnaire. The questionnaire was sent out to students and staff of the University of Konstanz. As a result of the questionnaire, we identified that most library users still experience the media disruption between digital and analog sources as a problem in their workflow. Participants complained about the costly process of digitizing quotes from printed sources or handwritten notes. A participant, for instance, stated: "ultimately everything is digitally written." For this reason many participants require a "full digitization of all library texts." One participant summarized the advantages of working with digital texts on electronic devices as "clean working, fast search and easily shareable with others". In contrast, other participants highlighted the importance of printed documents for their working practices. In their opinion, it is easier to compare the contents of several books spread on a desk than on digital devices. Furthermore, they value books for possibilities like the "fast skimming of pages to get a short overview", the better reading comfort as well as the easy marking and annotating of text. Also in research there are different works which highlight these qualities of paper documents for knowledge work and require to mimic them with electronic devices (Kidd, 1994; Sellen & Harper, 2003). In brief, you can say that, regarding their working methodology, participants value the different qualities of digital and physical sources. For this reason, our work aims to bridge the media disruption, not by a full digitization of printed sources, but by merging the qualities of physical and digital sources in the context of the working practices of library users. We want to create a consistent method of working with digital and physical sources by giving physical books qualities of digital books and vice versa. In contrast to related works, we do not focus on advancing the interaction possibilities of paper. But focus on a user-centered interaction design. Based on the design framework Blended Interac-

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tion (Jetter, Reiterer, & Geyer, 2014), we designed a system considering humans' general skills and common sense knowledge to blend the qualities of digital and physical sources in an easy to understand and operate manner.

In the following, we introduce the design framework Blended Interaction and we present how we applied Blended Interaction to understand and sharpen the design of Integrative Workplace. We conclude with the results of our user study and a summary.

2. Blended Interaction

The goal of Blended Interaction is to enable a user-centered design of natural interactions in interactive spaces[1]. The framework tries to advance Mark Weiser's vision (Weiser, 1991) to create an "invisible" ubiquitous computing "that provides us with the great powers of digital computation in an unobtrusive manner, so that we are freed to use them without thinking and 'mental gymnastics' and to focus beyond computers on new goals" (Jetter et al., 2014). For that purpose it draws on the principles of Reality-based Interaction (Jacob & Girouard, 2008) and of Conceptual Blending (Fauconnier & Turner, 2002). Reality-based Interaction attempts to make human-computer interaction similar to the interaction with the real world. By drawing on humans' pre-existing knowledge and skills, the mental effort required to operate a system is reduced and users are free to focus on the actual task without their cognitive flow being interrupted by cumbersome interactions. Jacob et al. also highlight "the ability to go beyond a precise imitation of the real world" (Jacob & Girouard, 2008) as the source of the power of using computers. A guideline to design intuitive but expressive user interfaces is "to give up reality only explicitly and only in return of other desired qualities" (Jacob & Girouard, 2008) of the digital world. In contrast to Reality-based Interaction, Blended Interaction not only applies users' natural skills and pre-existing knowledge of the real world but also considers digital well-established concepts in the design of new user interfaces. As humans spend more and more time in the digital world, we cannot consider human thinking free from digital influences anymore and need to take them into account when designing new interaction concepts.

Conceptual Blending theoretically explains how human thinking subconsciously creates a new concept through projection from two existing input concepts. Therefore human mind connects the two input concepts on the base of a generic space. The generic space contains basic level concepts which are common to both inputs (e.g. both inputs are containers). On base of these commonalities, human mind blends both input concepts in an output concept that has a new and emergent structure which is not available from the inputs alone. Blended Interaction uses this process of indirect projection to theoretically explain that user interfaces only need to share selected aspects of reality for users to be able to understand and operate a new interaction design. This enables us to use computational power to go beyond what is possible in the real world by keeping a natural and intuitive interaction. In addition, Blended Interaction introduces the four domains of design as different perspectives on the interaction design to holistically support a certain task:

Individual Interaction: The goal is an intuitive handling by applying pre-existing skills and knowledge of the real and the digital world.

Social Interaction: A system should facilitate the social interaction between users having a common task and support collaborative working.

Workflow: Designers should consider the organizational workflow of a certain task and better supporting it in the interaction design.

Physical Environment: The architecture of a room and the form factors of digital devices (shape, display size) should be adjusted according to a certain task.

3. Applying Blended Interaction

In a first step, to limit the design domain, we analyzed different scientific disciplines and chose legal research for its clearly structured and systematic methodology. To understand legal working practices, a survey with law students who wrote a seminar paper in the summer semester break of 2012 (N=14) was conducted and the Blended Library questionnaire was re-evaluated, only considering participants with a background in jurisprudence (N=70). Similar to (Deininghaus & Möllers, 2010), who researched literary scholars, we wanted to know how law students interact with physical and digital documents to design a system which is useful in a real-world context. In contrast to their research, we are not focusing on the integration of digital material into a paper-centric process but on giving paper documents computer-based properties and digital documents real-world properties. Thereby we are following the vision of Newman and Wellner: to design a system where users are free "to choose either medium as the task requires without being constrained to the limitations of either" (Newman & Wellner, 1992). In the following chapters we analyze the results of this initial study in relation to the Blended Interaction domains of design. We will demonstrate how the framework guides the design process from the context analysis to the implementation of the interaction design. The social interaction domain of Blended Interaction is not addressed due to the fact that writing a legal paper mostly involves single person working.

3.1 Physical Environment

In legal work it is frequently necessary to compare opinions from different sources. For this reason, students who are working on a legal case have numerous opened books on their desks. They place them next to each other and, if space is limited, they also pile them to even have more information at a glance (Figure 1).

In contrast, digital devices do not facilitate this method because, as law students mentioned, on typically sized

1 For a more detailed description of the design framework Blended Interaction see (Jetter et al., 2014).

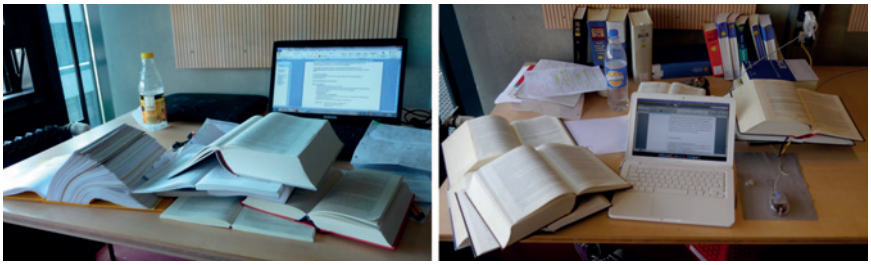

Figure 1: Two workplaces of law students with numerous piled and side by side situated books.

displays it is possible to at most place two documents beside each other. Additionally, some participants complained about the problem of losing track of the opened documents on their computers. On a digital device it is difficult to match a just read text passage to a source without looking for its title as all documents look similar and disappear behind the same icons. As opposed to this, the position of a physical book on a desk simplifies a subconscious mapping of a text passage to the according book without needing to know the title of a source. In terms of designing the physical environment, this highlights the importance of space for legal work. Law students need to have the possibility to clutter a tabletop with books, notes or other artifacts as it helps them to compare between sources and to keep an overview over the gathered information. Also in literature, the possibility to lay out information in space is an often cited need of knowledge work (Kidd, 1994; Sellen & Harper, 2003). For this reason a huge tabletop forms the base of the physical environment. In addition, a projector is mounted above the desk to augment the tabletop with digital contents (Figure 2).

Because the projector equips the physical environment with an infinite digital landscape, users are not constrained to the size of the tabletop, but are able to acquire as much space as needed in the digital world. By designing our physical environment as it is, we blend a physical tabletop with a digital landscape. In the prospective of legal work, this opens up new methods. Law students can now situate physical and virtual documents next to each other and thus cross-read between digital and analog sources. According to our goal to create a consistent method of working with digital and physical sources, users are also able to spatially arrange, move and pile digital documents in the same way as physical documents.

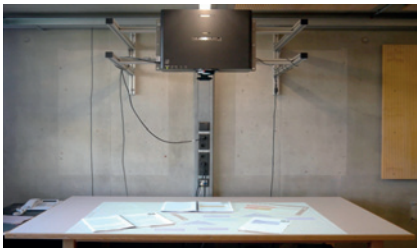

Figure 2: Physical environment of Integrative Workplace.

3.2 Individual Interaction

As already mentioned, excerpting information from analog sources with today's technologies still means additional working steps and thereby the interruption of the cognitive flow. For this reason, we want to blend the easy excerpting of text from digital sources with printed documents (similar to (Wellner, 1991)). To facilitate a consistent working method for electronic and printed texts, we use the same pen and the same interaction technique to excerpt text in printed and digital documents. In addition to (Steimle, 2009), who firstly introduced this approach, our system enables a consistent real-time feedback on interactions with both, digital and physical documents (Figure 3).

With a digital pen users can select text, as they would do in mouse operated applications. For instant user feedback, the projector highlights that text successively. The pen can be used to drag a copy of the selected text and drop it at a desired location on the tabletop. In terms of Blended Interaction, the strongly developed body skill of using a pen in combination with the digitally well-established concept of (text) selection on electronic devices, blends the computational power used to digitize printed text in an easy to understand and to use manner.

By using bimanual pen and touch interaction a new challenge arises. Because on digital devices pen and touch are not restricted to their inherent functionality, it is necessary to define an easy to understand way to differentiate between interactions which can be performed by the pen and interactions which are performed using touch. This is a controversially discussed topic in research with different approaches to handle it (Frisch, Heydekorn, & Dachselt, 2010; Hinckley et al., 2010). In our system, we take the behaviors that people already exhibit when working with pen and paper as foundation for our pen and touch gestures: the pen is used to write or draw and touch to manipulate. According to (Hinckley et al., 2010) this approach offers a consistent and rich designed input vocabulary which helps to go beyond

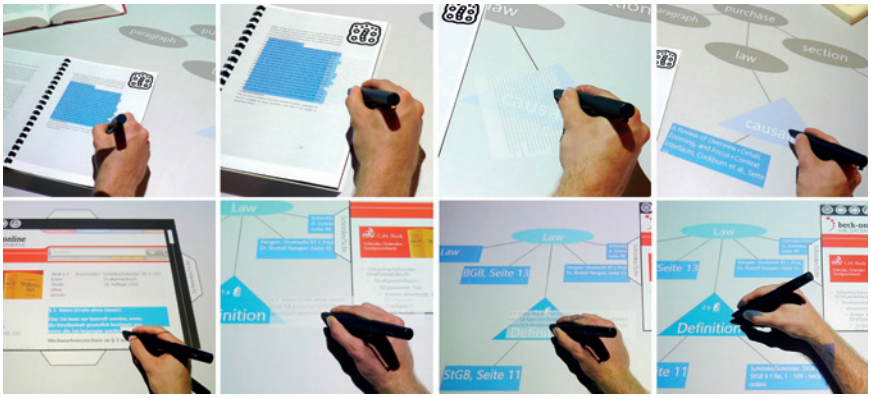

Figure 3: Selecting, dragging and dropping text of a physical book (top) and of a digital document (bottom).

the possibilities of a real-world pen and paper interaction. In terms of Blended Interaction, we used pen and touch as the first input space and the computational power, for example to dynamically align digital documents or to recognize shapes and handwritten text, as second input space. The common generic space that a pen is used to write or draw and touch to manipulate keeps it easy to understand and to operate the additional expressive power.

3.3 Workflow

The analysis of the workflow of law students revealed that the index of a book is often used as a starting point for a literature review by taking a catchword of a legal record to find relevant information. Participants also emphasized full-text search in digital documents as one of the major benefits of using computers. For this reason, we want to augment physical documents with a digital full-text search.

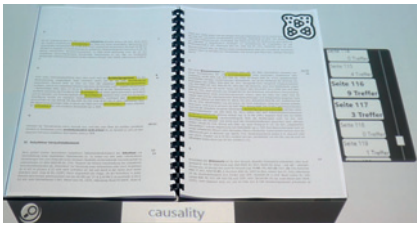

Figure 4: Full-text search in physical documents.

In Integrative Workplace, a full-text search in a physical document highlights the matching words on the opened pages. Full-text search in paper documents was already introduced in FACT (Liao, Tang, Liu, Chiu, & Chen, 2010). However, an interactive scrollable list to the right of the book displays the matching words per page for the entire book (Figure 4).

The context analysis also made clear, that law students would value the possibility to save excerpts from physical and digital documents at one place to have all information at a glance. In our prototype this place is the tabletop. By dropping them on it, excerpts of physical and digital sources are saved as textual items which can be arrange in a mind map (Figure 3, right). We chose a mind map as graphical visualization because it leaves users the

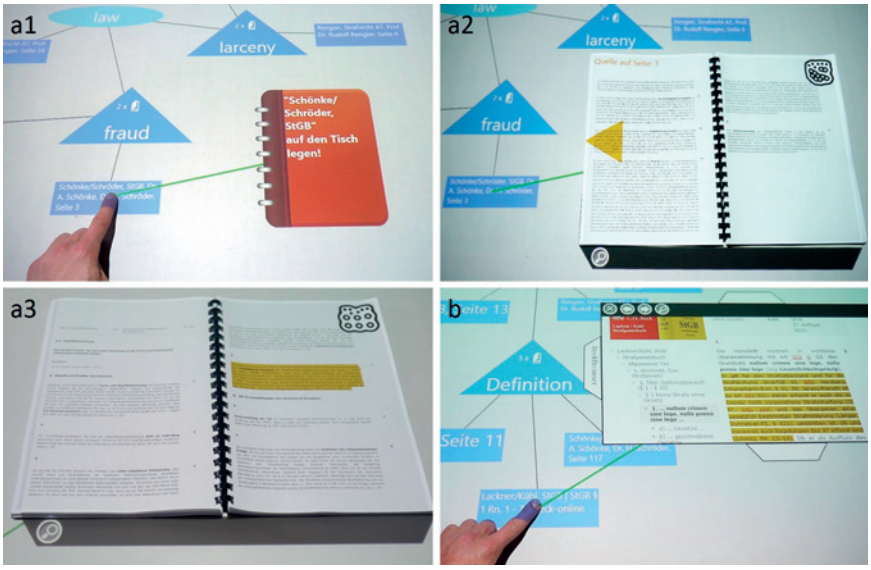

Figure 5: Backtracking from a mind map text item to its physical (a) or digital (b) source.

structural freedom to decide how they arrange items. In this way, beside their usual way of working linearly, law students also can draw, for example, an arboreal visualization which matches their approach when working at a civil law case.

Analyzing their workflow, it appeared that law students often search for excerpted text passages to reread them in context. Therefore we designed the reference backtracking function which guides users to the original page of an excerpt of both, digital and physical sources. In case of a digital source, applying a hold gesture on a text item displays the according webpage and highlights the excerpted passage (Figure 5, b). When backtracking to a physical source, the source's title is displayed on the tabletop after the hold gesture was performed (Figure 5, a1). If then, the according source is placed on the desk, the book is augmented with an arrow, which indicates the direction to flip pages for finding the original page of an excerpt (Figure 5, a2). On the original page the excerpted passage is highlighted (Figure 5, a3). This functionality, to our knowledge, is not offered by related works.

4. Technical Implementation

As people refuse to put objects on horizontal displays (Morris, Brush, & Meyers, 2008), we implemented our own interactive desk which preserves the solid character of a tabletop allowing law students to work at our system without being overcautious (permitting them to put physical books and other personal belongings on it). To be able to interact with digital documents like with physical documents, the interactive desks enables pen and touch interaction. Therefore its tabletop consists of four layers: a dot pattern, a glass pane, a capacitive sensor and a regular table board (Figure 6). Touch interaction is realized using the capacitive sensor Displax Skin Multitouch[2]. For pen interaction, the tabletop is augmented with a non-repeating dot pattern enabling the usage of the Anoto Digita Pen[3]. To use the digital pen as a regular input device, the InputFramework developed by the Media Interaction Lab of FH Hagenberg[4] is used.

Furthermore, to be able to evaluate our proposed interaction design, we mimicked digitally manipulable physical books. Therefore the Anoto dot pattern and a fiducial marker is printed on every page of a book (Figure 5, a3). In addition, the digital representation of each physical book is parsed before usage.

2 http://www.displax.com/en/products/products/skin-multitouch.html
3 The Anoto Digital Pen which has a digital camera close to the pen point works by recognizing its position on a non-repeating almost invisible dot pattern (http://www.anoto.com/).
4 http://mi-lab.org/

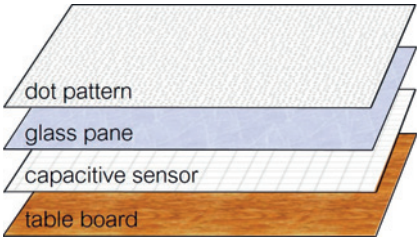

Figure 6: The layers of the tabletop of the interactive desk.

For every page, the containing words and their position on the page are saved in an XML file. Processing the camera stream, the reacTIVision[5] framework is used to recognize fiducial markers on the tabletop. Based on these makers, Integrative Workplace identifies the documents on the desk and their physical location. If a user marks a certain word in one of the books, the Anoto Digital Pen determines its position on the page's dot pattern and sends it to Integrative Workplace (Figure 7). By knowing the positon of the pen, the system can retrieve the underlying word and its position from the XML file. Knowing the position of the book on the desk and of the marked word on the page of the book, the projector can now highlight the word and thereby give feedback on the user's interaction. In contrast to related works, this implementation allows using the digital functionalities of physical books (excerpting, full-text search, backtracking to source) on any number of books in parallel.

5. User Study

To evaluate our interaction design, nine law students (three females, six males) were asked to work on a legal case using Integrative Workplace. In a screening, we ensured that they had sufficient skills in legal working[6]. The issue they solved was situated in the areas of German criminal and inheritance law. After a short introduction into the system and a training phase, the participants had 30 minutes to work on the case. During this time they were asked to think aloud. In the following, the three main findings of our user study are presented.

5.1 System Design

All participants perceived the functionality of Integrative Workplace as futuristic and beyond what they think computers can offer. This became apparent in the reactions during the introduction to the system (e.g., "nice invention", "I'm amazed"). With the study, we want to determine if our design helps users to understand and interact with the new and unfamiliar functionality. Therefore we asked the participant to fill the System Usability Scale (Brooke, 1996), as a good design can be seen as the base of a good usability. The analysis revealed a SUS Score of 66.94 giving the system an adjective usability rating in between OK and GOOD and classifying it as marginally acceptable (Bangor, Kortum, & Miller, 2008). To investigate if users appreciate the features of Integrative Workplace, we asked the participants about the biggest advantage of the system. The two most frequently named responses were the easy copying of text from physical books (four participants) and the possibility to deposit excerpted text from digital and physical sources in one place (four participants). Because both features come with blending the qualities of digital and physical books, this can be seen as further indication that our design enables an intuitive usage of the new computational power.

As "the usability of any tool or system has to be viewed in terms of the context in which it is used" (Brooke, 1996) the detected SUS score, to a certain extent, reflects the appropriateness of Integrative Workplace for legal work. To further investigate what effect our design has on juristic working practices, we asked students if Integrative Workplace supports legal work. On a five point Likert scale (1="I agree", 5= "I disagree"), they answered the question positively with an average value of 1.78. Asked for a reason, the participants most frequently named the high clarity over excerpts as all are saved at one place (five participants). One problem of the design of Integrative Workplace, which was revealed by the study, is that a mind map is not a beneficial visualization in matters of legal work. Most participants suggested to somehow design a linear visualization as it better fits juristic working practices: "In law, there is a distinct evaluation order of legal issues. It is not possible to reflect this order with a mind map".

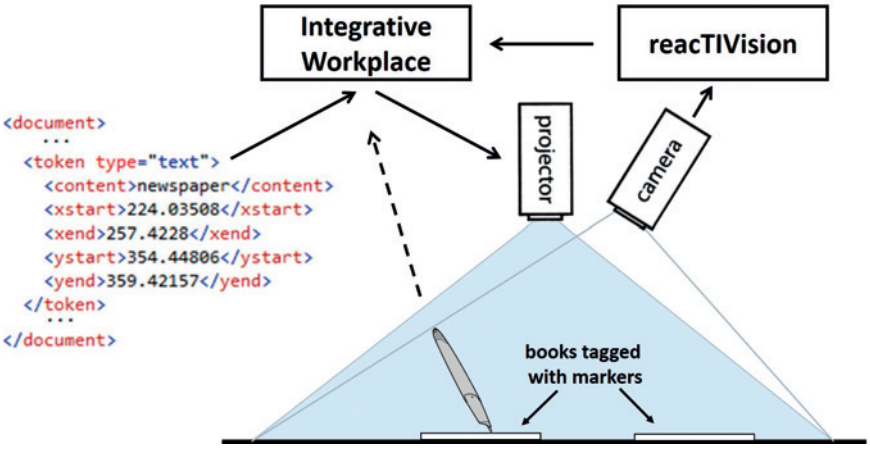

Figure 7: Implementation to mimic digitally manipulable physical books.

5.2 Blending Digital Functionality with Real-World Objects

Observing participants' usage of full-text search in physical books, we found interesting incidents regarding the blending of digital functionality with real-world objects. All three participants who applied a full-text search in a book, tried to open book pages by touching the digital

5 reacTIVision is a computer vision framework for tracking fiducial markers attached onto tangibles (http://reactivision.sourceforge.net/).

6 On average they studied 6.3 semester (SD = 2.9 semester) and wrote 3.4 seminar papers (SD = 1.2 seminar papers).

visualization which displays the matching words per page. These incidents highlight that the participants did not distinguish between the digital visualization and the physical book but rather perceived both as one unity. Interacting with the unfamiliar UI, the participants draw on their knowledge of the digital world, that touching a label representing a certain page normally opens the according page on electronic devices, and applied it to the physical book. In terms of Blended Interaction it is interesting to acknowledge that they did not employ an interaction concept known from reality to control the virtual world, but used a digital interaction concept to try to control a real-world object. This indicates that even for futuristic functions, like automatically flipping physical pages, interaction designers can rely on the fact that users subconsciously apply their pre-knowledge to operate unfamiliar functionality. At the same time these incidents highlight the pervasiveness of digital interaction concepts in the minds of the users, substantiating the statement of the next chapter.

5.3 Digital Concepts are Part of Users' Reality

A design decision which caused interaction problems is using the pen to write or draw and touch to manipulate. Although we adapted this behavior from reality, seven out of nine participants tried, for example, to move a mind map item with the pen or to draw a mind map item using a finger. One participant stated: "I didn't know when I had to use the pen and when the finger". Similar findings have been made in literature (Frisch et al., 2010; Matulic & Norrie, 2012). Through the proliferation of tablets and smartphones "people are gradually developing a habit of using their fingers for all kinds of interactions, including quite a few that one would think would be more adequately performed with a pen" (Matulic & Norrie, 2012). In terms of Blended Interaction, this is a nice example, which shows that digitally well-established concepts became a part of the users' reality and that it is necessary to consider them when we want to design interfaces which are intuitive to use and easy to understand.

6. Conclusion

This work presents a user interface which is blending the qualities of digital and physical sources in the context of jurisprudence. Using Blended Interaction's four domains of design, we analyzed legal working practices to implement a system which supports legal work by augmenting physical sources with qualities of digital sources and vice versa. To prove our design we conducted a user study with nine law students who worked on a legal case. The enthusiastic reactions of the participants revealed that the functionality of our system was beyond what they thought computers can offer. Still we found strong indications that our interaction design managed to blend the qualities of physical and digital sources in a way users can understand and interact with the new and unfamiliar functionality. Participants did not distinguish between the digital visualization and the physical book but perceived both as a unity. The positive feedback of participants regarding the support of legal working practices also indicated that the system is usable in the context of its use case. In addition, incidents of the user study give evidence that digital well-established concepts became a part of humans' reality and need to be considered in the design of new user interfaces. These results and a good performance of the system in the System Usability Scale encourage us to continue to use Blended Interaction in the design process of novel user interfaces. In future work, we intend to use Integrative Workplace to conduct a systematic evaluation that examines how digital desks might change knowledge work practices and its outcomes compared to tools used at nowadays desks (Gebhardt, Rädle, & Reiterer, 2014).

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